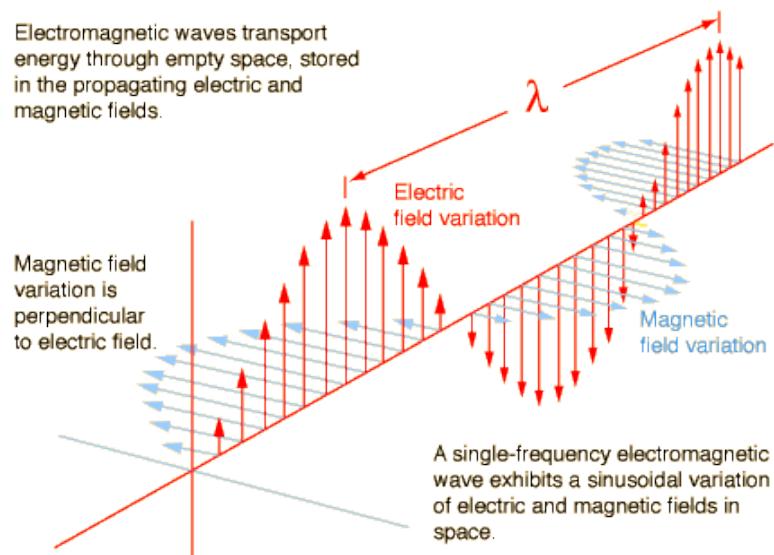


# LECTURE 11

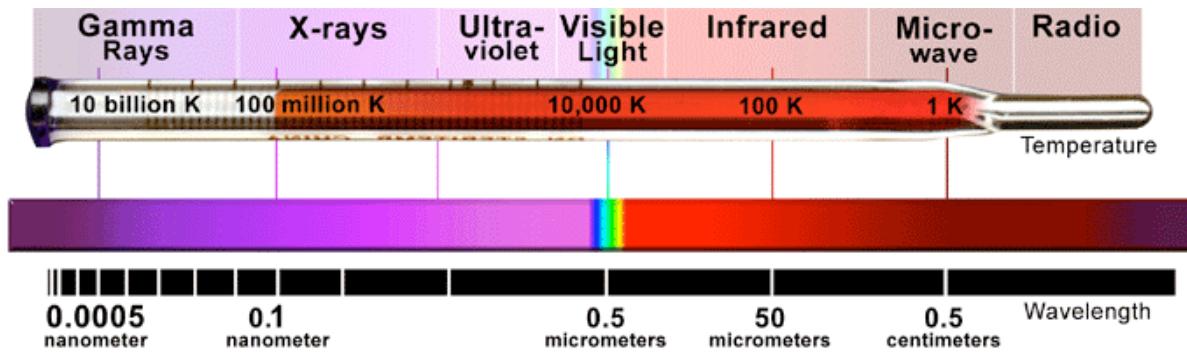
## High Energy Telescope Design and Instrumentation

### The Electromagnetic Spectrum

- Primary source of info about the Universe
- But...
  - Neutrinos
  - Gravitational waves
  - Things that fall to Earth

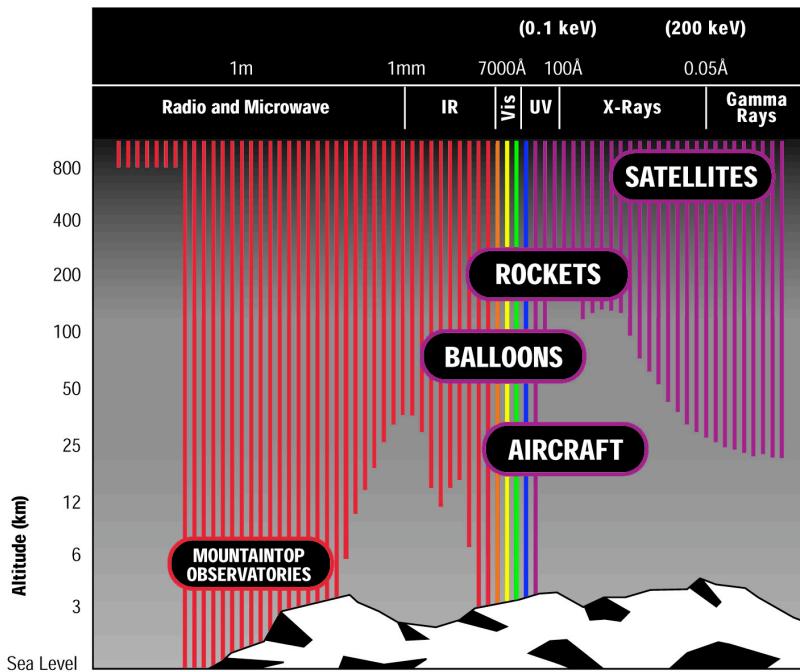


- Thermal processes → blackbody radiation



- Most objects radiate between about 3 K and 100,000 K
- Non-thermal processes
  - Accretion
  - Powered by gravitation
  - Magnetic field interactions
  - Bremsstrahlung radiation
  - Synchrotron radiation
  - Compton scattering
  - Atomic state transitions
- Can have effective temperatures of millions or billions of K.

# Earth's Atmosphere



- Transparent in 3 bands
  - Optical
  - Near-infrared
  - Radio
- *High energy astrophysics must be done from space.*

## **Ultraviolet Astronomy**

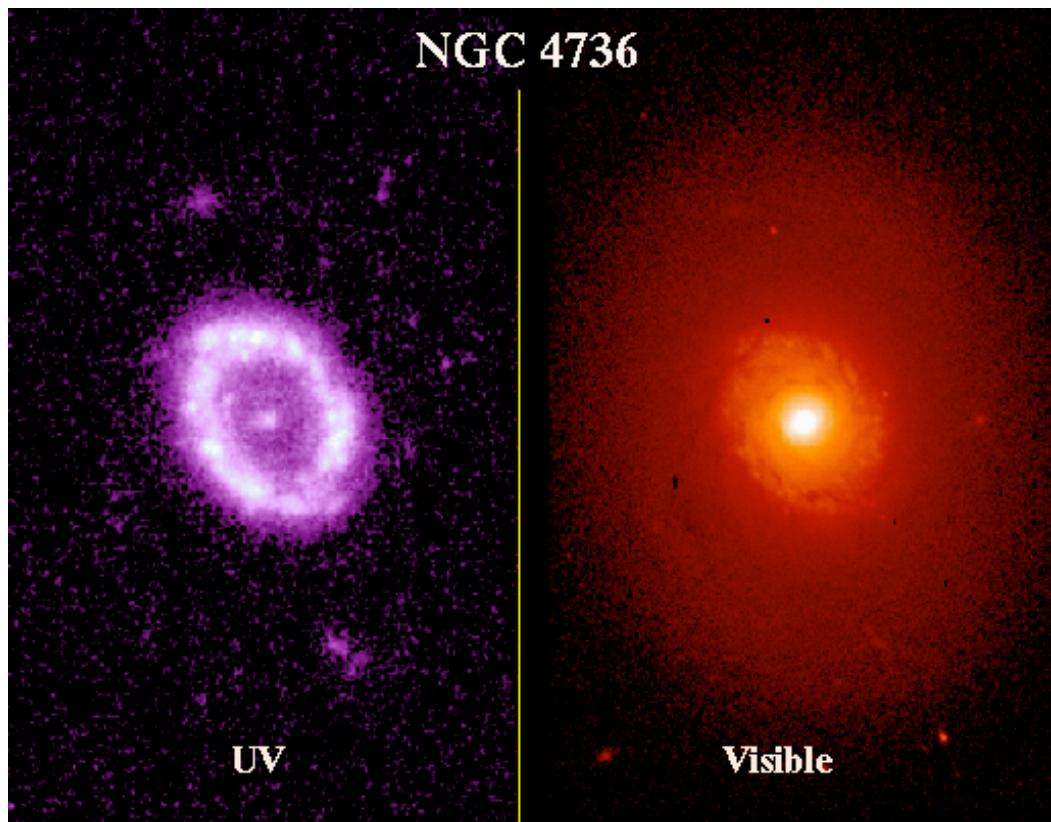
- Similar to optical astronomy
- High-altitude or space-based observatories
- Atmospheric cut-off: 3200 Å
- Interstellar medium
  - Lyman edge of HI at 910 Å
- Near Ultraviolet
  - 2000–3200 Å
- far Ultraviolet
  - 910—2000 Å
- extreme Ultraviolet
  - 70–9100 Å

## **Ultraviolet Telescopes**

- Similar to optical telescopes
- Poor reflectivity/transmission of optical elements
- Optical contamination
- CCD detectors
  
- Low background
- Extinction can be high

# Ultraviolet Astronomy

- Hot stars
  - O and B stars
  - Horizontal branch stars
- Star forming regions
- Supernovae
- Quasars



## X-Ray Astronomy

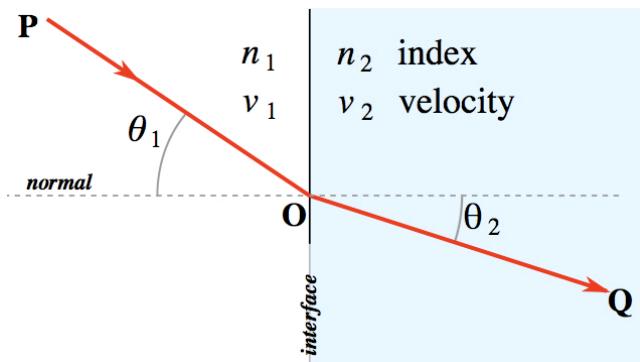
- Energies, not wavelengths
- Electron volts (eV)
  - $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$

$$E = 12,400 \text{ \AA} / \lambda \text{ (eV)}$$

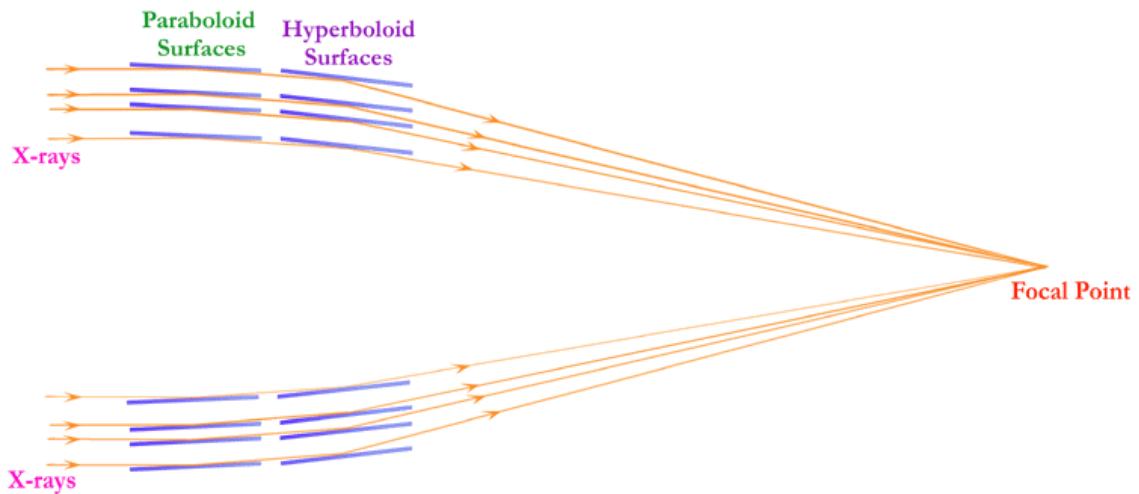
- Soft X-ray band
  - 0.1–1 keV
- Hard X-ray band
  - 1–100 keV

# X-Ray Telescopes

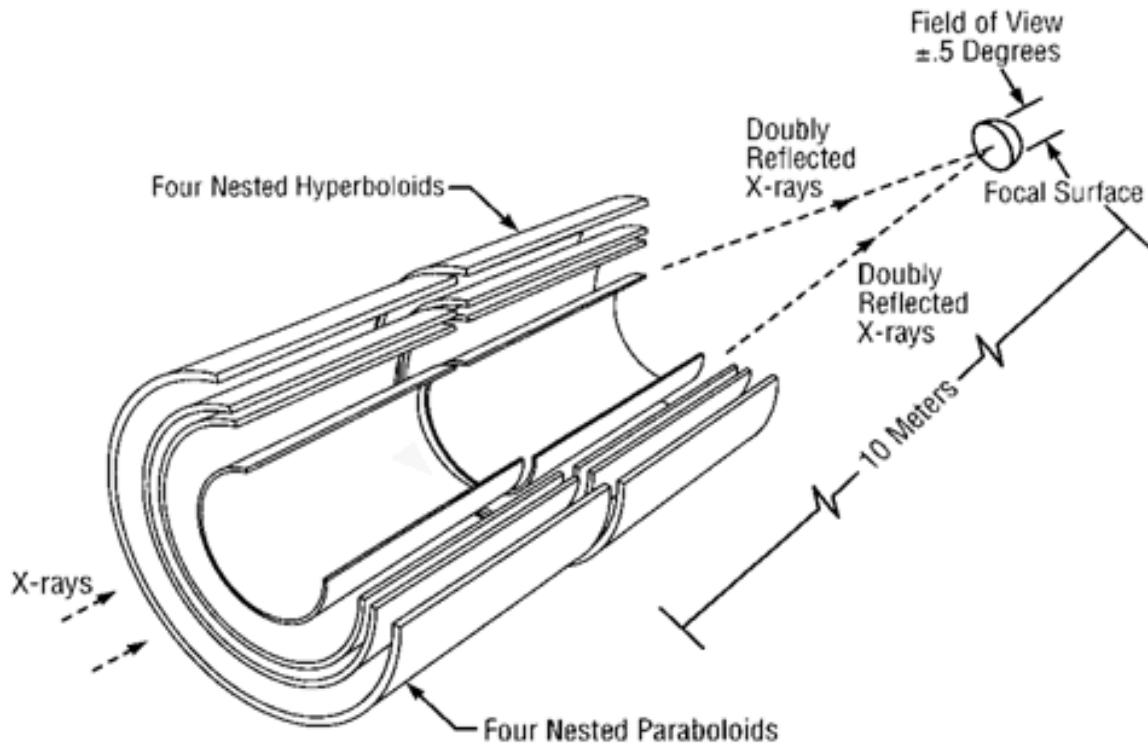
- Most materials have  $n \approx 1$  for X-ray photons
- Conventional optics do not work



- Grazing incident optics



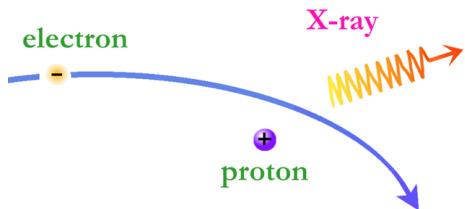
- Wolter design



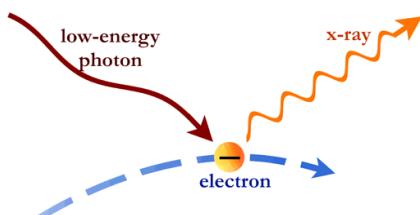
- Nested mirror shells
- Increase number of photons reaching detector
- CCD detectors
- Current *X*-ray missions
  - *Chandra*
  - *Suzaku*
  - *Swift*
  - *XMM-Newton*
  - *XTE*

# Some X-Ray Processes

- Thermal Bremsstrahlung



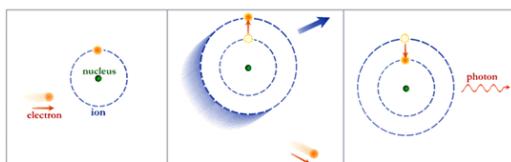
- Inverse Compton Scattering



- Synchrotron Radiation



- Atomic Emission

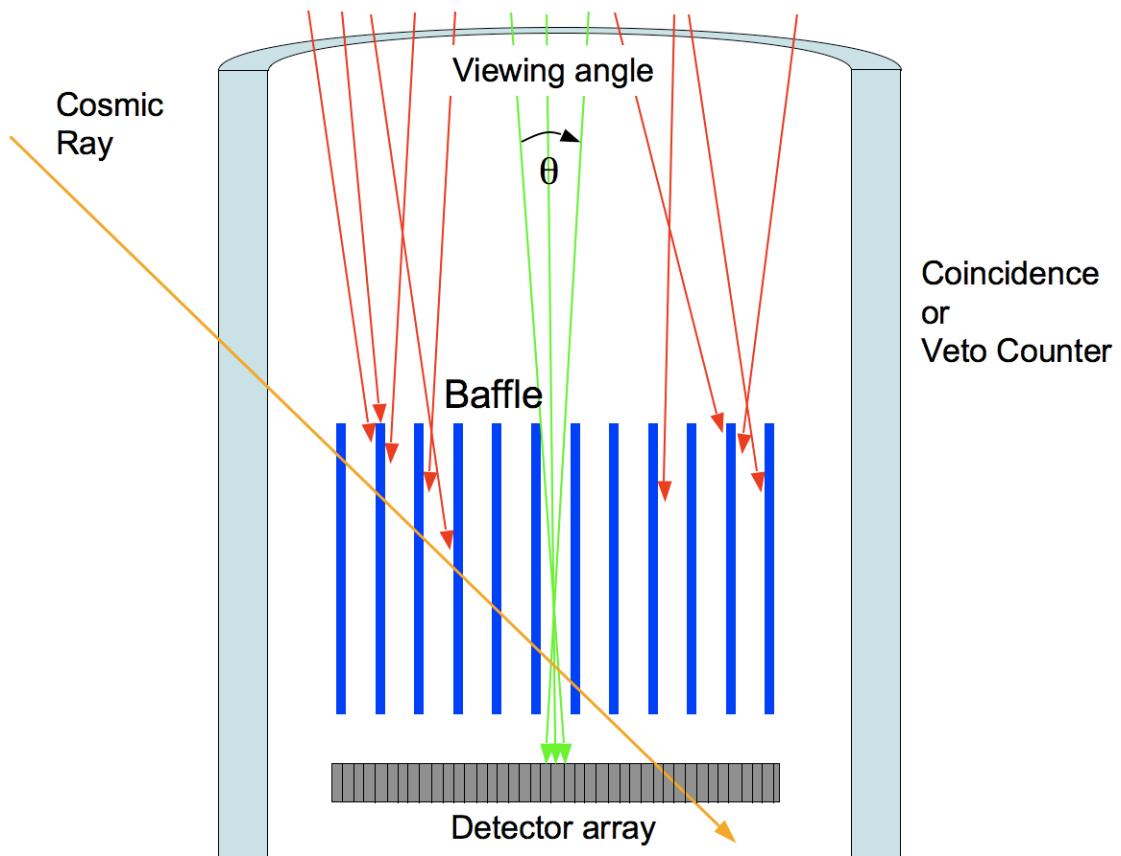




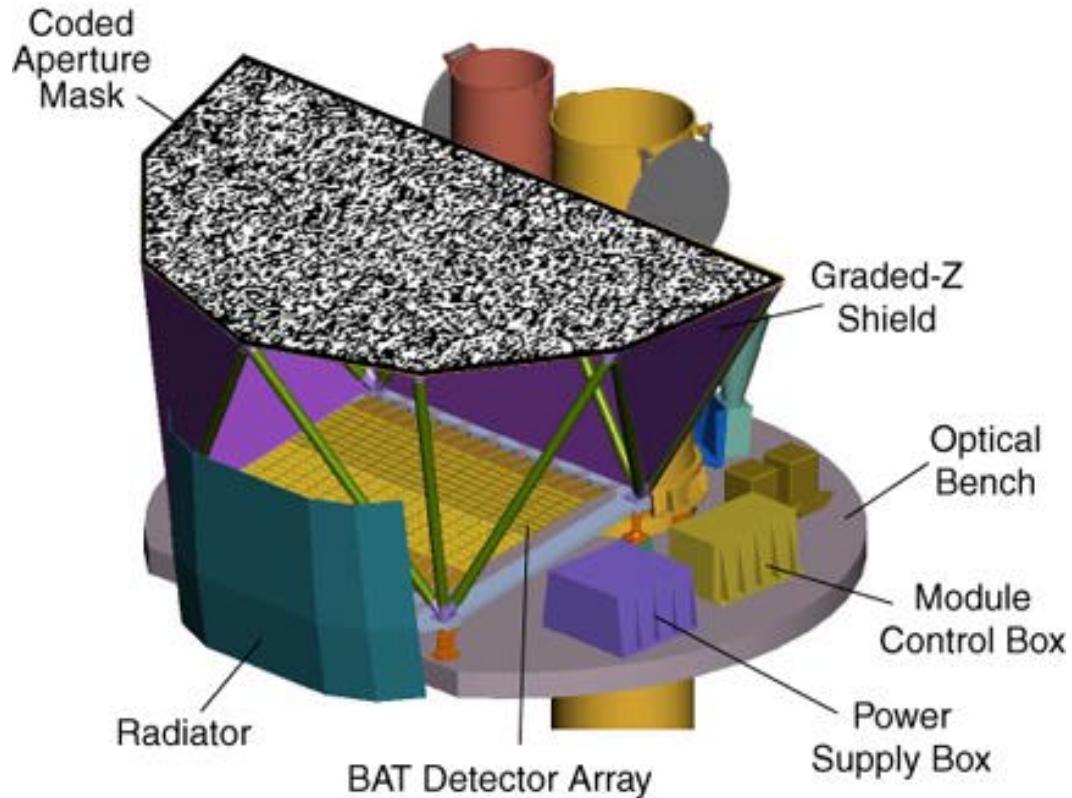
- Non-thermal processes
- Stellar flares
- Accretion discs
- Gamma-ray bursts
- Gas in galaxy clusters

## Gamma-Ray Astronomy

- Highest energy photons
- 100 keV – 1 TeV (or higher)
- Gamma-ray photons do not “see” optics
- Hard to localize



- Coded Mask
- Random (but known) pattern of tiles
- “shadow” cast on detector
- Fourier transform shadow pattern
- Low resolution image



# Gamma-Ray Astronomy

- Non-thermal sources
  - Accretion discs
  - Gamma-ray bursts
  - Pulsars

